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GRAINS RESEARCH & DEVELOPMENT CORPORATION

LUPIN

SECTION 5

WEEDS AND HERBICIDES

OVERVIEW | HERBICIDE TYPES AND USE | MANAGING RESIDUAL HERBICIDE ISSUES | IMPORTANCE OF INTEGRATED WEED MANAGEMENT (IWM) | SUMMER WEED CONTROL | GRASS WEED CONTROL IN LUPIN | BROADLEAF WEED CONTROL IN LUPIN | CROP-TOPPING FOR WEED CONTROL | HARVEST WEED SEED CONTROL (HWSC) TACTICS | WEED DETECTION TECHNOLOGY | DECISION SUPPORT TOOLS

Weed management and herbicide use

5.1 Overview

Weed control in Western Australian lupin crops has long been a challenge due to poor crop competition and limited crop herbicide tolerance.

Research and experience in this State is finding integrated weed management (IWM) strategies that combine sustainable herbicide use/rotations coupled with lupin variety choice, time of sowing, improved crop competitiveness and harvest weed seed destruction can significantly reduce seedbanks of some weeds within three to five years.

Using a wide range of weed control tactics will also help supress ongoing risks of herbicide resistance and facilitate long-term herbicide sustainability.

Major weeds that impact on lupin production in WA are:

- Annual ryegrass (*Lolium rigidum*)
- Wild oats (*Avena fatua L.*)
- Brome grass (*Bromus diandrus* and *B. rigidus*)
- Barley grass (*Hordeum*)
- Wild radish (*Raphanus raphanistrum L.*).

Other weeds impacting on lupin productivity in this State include:

- Capeweed (*Arctotheca calendula*)
- Wild mustard (*Sysimbrium orientale*)
- Doublegee (*Emex australis*)
- A range of summer weeds.

Typically, it has been easier, more effective and cheaper to use selective herbicides to remove grassy weeds in lupin (and other broadleaf) crops and to control broadleaf weeds in cereal crops.

MORE INFORMATION

GRDC Hot Topic 'Lupin weed control': https://grdc.com.au/Media-Centre/Hot-Topics/Lupin-weed-control

GRDC 'Grain Legume Handbook, Chapter 5 Weed Control': https://grdc.com.au/grainlegumehandbook

GRDC Fact Sheet 'In-crop herbicide use': Use grdc.com.au/GRDC-FS-InCropHerbicideUse

GRDC 'Weed seedbank destruction' video: https://www.youtube.com/watch?v=6nTo_n47TxE#t=12

GRDC 'Weed ID: The Ute Guide' App: https://grdc.com.au/apps

GRDC Ground Cover Supplement 'Herbicide Resistance': https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS104

WeedSmart: www.weedsmart.org.au

WeedSmart App: https://grdc.com.au/apps

DPIRD 'Crop weeds': https://www.agric.wa.gov.au/pests-weeds-diseases/weeds/crop-weeds

DPIRD 'Lupin diagnostic tool': https://www.agric.wa.gov.au/pests-weeds-diseases/weeds/crop-weeds

5.2 Herbicide types and use

The two types of herbicides are residual and non-residual. Residual types remain active in the soil for an extended period (months) and can act on successive weed germinations. Residual herbicides must be absorbed through the roots or shoots, or both.

Examples of residual herbicides include isoxaflutole, imazapyr, chlorsulfuron, atrazine and simazine. The persistence of residual herbicides is determined by a range of factors. These include application rate, soil texture, organic matter levels, soil pH, rainfall and irrigation, temperature and the herbicide characteristics. The persistence of herbicides will affect the enterprise crop rotation.

Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity and are quickly deactivated in the soil. They are either broken down or bound to soil particles, becoming less available to growing plants. They also may have little or no ability to be absorbed by roots.

Herbicides are applied pre or post-emergent. Pre-emergent refers to application of the herbicide to the soil before weeds have emerged. Post-emergent refers to foliar application of the herbicide after the target weeds have emerged from the soil.

A list of herbicide modes of action can be found here https://www.croplife.org.au/resistance-strategy/2017-herbicide-mode-of-action-groups/

The Australian Pesticides and Veterinary Medicines Authority (APVMA) has a complete list of registered herbicide products and actives at https://apvma.gov.au/

As highlighted in Table 1, including lupin in cereal rotations facilitates the use of herbicide modes-of-action (MOA)/actives that cannot be used in cereal phases to control grassy weeds and crop volunteers.

FEEDBACK

Table 1: Registered herbicides for use in lupin[1]. NOTE rates are per hectare.

	trifluralin	pendimethalin (e.g. Stomp)	triallate (e.g. Avadex)	simazine 50% flowable (on light soils) rates can be 2-3 L on gravelly-loams	simazine 50% + atrazine 50%	diuron 50% flowable	simazine 50% flowable top-up	diflufenican (e.g. Brodal)	diflufenican + metribuzin (750 g/kg and for some varieties)	picolinafen (e.g. Sniper)	metosulam (e.g. Eclipse)	tepraloxydim (e.g. Aramo)	sethoxydim	clethodim (e.g. Select) at 240 g/L	Butroxydim (Factor)	fluazifop (e.g. Fusilade)	haloxyfop 520g/L (e.g. Verdict with Uptake)
Group	**D**	**D**	**J**	**C**	**C**	**C**	**C**	**F**	**F+C**	**F**	**B**	**A**	**A**	**A**	**A**	**A**	**A**
Annual ryegrass	1.2-1.7 L	1.2-1.7 L		1.0-2.0 L (S)	0.5-1.0 L + 0.5-1.0 L (S)	2.0 L	0.75-2.0 L (S)					175-300 mL	0.5-1.0 L	150-500 mL	80-180 g	250 mL or 500 mL (weed size)	75 mL or 100 mL (weed size)
Brome grass				1.0-2.0 L (S)	0.5-1.0 L + 0.5-1.0 L (S)		0.75-2.0 L (S)					175-300 mL		175-500 mL		250 mL or 500 mL (weed size)	50 mL or 75 mL (weed size)
Barley grass				1.0-2.0 L (S)	0.5-1.0 L + 0.5-1.0 L (S)		0.75-2.0 L (S)					175-300 mL		175-500 mL	80-180 g	250 mL or 500 mL (weed size)	50 mL or 75 mL (weed size)
Silver grass				1.0-2.0 L	0.5-1.0 L + 0.5-1.0 L (S)		0.75-2.0 L										
Wild oat	1.2-1.7 L		1.6 L (Avadex Xtra at 500 g/L triallate)	1.0-2.0 L	0.5-1.0 L + 0.5-1.0 L (S)		0.75-2.0 L (S)					175-300 mL	0.5-1.0L	175-500 mL	80-180 g	250 mL or 500 mL (weed size)	37.5 mL or 50 mL
Wild radish				1.0-2.0 L	0.5-1.0 L + 0.5-1.0 L	2.0 L	0.75-2.0 L	100-200 mL	100-150g + 100 mL	33-50g	50-70 mL						
Wild turnip				1.0-2.0 L	0.5-1.0 L + 0.5-1.0 L	2.0 L	0.75-2.0 L	100-200 mL									
Wild mustard				1.0-2.0 L	0.5-1.0 L + 0.5-1.0 L		0.75-2.0 L	100-200 mL									

S – suppression only

1 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

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	trifluralin	pendimethalin (e.g. Stomp)	triallate (e.g. Avadex)	simazine 50% flowable (on light soils) rates can be 2-3 L on gravelly-loams	simazine 50% + atrazine 50%	diuron 50% flowable	simazine 50% flowable top-up	diflufenican (e.g. Brodal)	diflufenican + metribuzin (750 g/kg and for some varieties)	picolinafen (e.g. Sniper)	metosulam (e.g. Eclipse)	tepraloxydim (e.g. Aramo)	sethoxydim	clethodim (e.g. Select) at 240 g/L	Butroxydim (Factor)	fluazifop (e.g. Fusilade)	haloxyfop 520g/L (e.g. Verdict with Uptake)
Group	**D**	**D**	**J**	**C**	**C**	**C**	**C**	**F**	**F+C**	**F**	**B**	**A**	**A**	**A**	**A**	**A**	**A**
Doublegee				1.0-2.0 L	0.5-1.0 L + 0.5-1.0 L	2.0 L	0.75-2.0 L										
Capeweed				1.0-2.0 L	0.5-1.0 L + 0.5-1.0 L	2.0 L	0.75-2.0 L	200 mL (S)	100-150 and 100 mL (S)	50 mL (S)	50 mL and 100 mL Brodal (S)						
Wireweed	1.2-1.7 L	1.5-2.25 L (pre-plant incorp)			0.5-1.0 L + 0.5-1.0 L												

S – suppression only

(SOURCE: DPIRD/Protech Consulting)

MORE INFORMATION

Pulse Australia 'Lupin weed management': http://www.pulseaus.com.au/growing-pulses/bmp/lupin#weed-management

HerbiGuide: http://www.herbiguide.com.au/

Australian Glyphosate Sustainability Working Group: http://www.glyphosateresistance.org.au/

Adding lupin to the crop sequence also reduces carry over of inoculum from root and foliar diseases to provide a cereal disease break.

Effective IWM programs on individual properties will optimise opportunities to use selective herbicides in each crop phase of the rotation and reduce weed burdens for subsequent crops.

Without control of grass and broadleaf weeds, it has been estimated that yields in narrow leafed lupin crops can fall by as much as 65 percent. But there is significant reliance on six herbicide MOA in WA – as shown in Table 1 – and multiple herbicide resistance is a major issue for annual ryegrass and wild radish.[2]

Pre-emergent herbicides registered for use in WA lupin crops include:

- Simazine (Group C)
- Diuron (Group C)
- Atrazine (Group C)
- Triallate (Group J)
- Pendimethalin (Group D)
- Trifluralin (Group D).

Post-emergent herbicides registered for use in WA lupin crops include:

- Simazine
- Metribuzin (Group C)
- Diflufenican (Group F)

2 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

- Metosulam (Group B)
- Haloxyfop (Group A)
- Clethodim (Group A).

For long-term, effective and sustainable weed control and herbicide efficacy, the key is to use a combination of herbicide, physical and cultural management tactics.

Newer narrow leafed lupin varieties, such as PBA Leeman, PBA Jurien, PBA Barlock and Mandelup, have been shown to be higher yielding than older varieties under weed pressure and have better tolerance to some key herbicides, as illustrated in Table 2.

Table 2: Lupin variety response to herbicides in Western Australia 2005-2014.[3]

This research was conducted in the WA grainbelt (Eradu and Wongan Hills) to determine if new and existing varieties of narrow leafed lupin vary in tolerance to commonly used herbicides.

The sensitivity of the variety is summarised, using the following symbols based on the yield responses across all trials:

N (w/z) narrow margin, significant yield reductions at higher than the label recommended rate, but not at the label recommended rate.
Significant event occuring in w trials out of z trials conducted. Eg (2/5) = tested in 5 trials, 2 trials returing a significant yield loss.

x% (1/z) yield reduction (warning) significant yield reduction at recommended rate in 1 trial only out of z trials conducted.

x-y% (w/z) yield reductions (warning) significant yield reductions at recommended rate in w trials out of z trials conducted.

– not tested or insufficient data

✓ no significant yield reductions at the label recommended rates in (z) trials.

Always follow label recommendations. The organisations involved in this research do not endorse the use of herbicides above the registered rate or off label use of herbicides or tank mixes. Any research with unregistered agricultural chemicals or of unregistered products reported in this GrowNote™ does not constitute a recommendation for that particular use by the author/s or the researcher/s organisation. All agricultural chemical applications must accord with the currently registered label for that particular pesticide, crop, pest and region. It must be emphasised that crop tolerance and yield responses to herbicides are strongly influenced by seasonal conditions.

Herbicides (Rates/ha)	Timing	Year of Testing	Coromop®	Jenebillup®	Mandelup®	PBA Barlock®	PBA Gunyidi®	PBA Jurien®	Pootallong®	Tanjil®
Year of Testing and Trial sites			2005-06, 12-14 AB	2006, 08 B	2005-06, 08-11 AB	2011-13 A	2009-12 A	2012-14 A	2005 A	2005-06 AB
Simazine 500 2 L (*simazine*)	Pre-seeding	2005-06, 08-14	N (2/5)	✓ (2)	N (2/6)	5 (1/3)	N (1/4)	N (1/3)	N (1/1)	N (1/2)
Diuron 500 2 L (*diuron*)	Pre-seeding	2008-14	10 (1/3)	✓ (1)	N (3/4)	N (3/3)	N (4/4)	N (2/3)		
Simazine 500 2.0 L + atrazine 500 1.0 L (*simazine + atrazine*)	Pre-seeding	2005-06,08	✓ (2)	✓ (2)	✓ (3)	-	-	-	✓ (1)	10 (1/2)
Simazine 2 L+ diuron 1 L + metribuzin 750 133 g (*simazine + diuron + metribuzin*)	Post-emergent	2005-06	✓ (2)	✓ (1)	✓ (2)	-	-	-	✓ (1)	✓ (2)

3 Dhammu, H, DAFWA research officer (2017), (08) 9690 2217, harmohinder.dhammu@agric.wa.gov.au

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Herbicides (Rates/ha)	Timing	Year of Testing	Coromop(t)	Jenebillup(t)	Mandelup(t)	PBA Barlock(t)	PBA Gunyidi(t)	PBA Jurien(t)	Pootallong(t)	Tanjil(t)
Year of Testing and Trial sites			2005-06, 12-14 AB	2006, 08 B	2005-06, 08-11 AB	2011-13 A	2009-12 A	2012-14 A	2005 A	2005-06 AB
Boxer Gold® 2.5 L (*S-metolachlor + prosulfocarb*)	Pre-seeding	2008-10,12	✓ (1)	✓ (1)	✓ (3)	✓ (1)	N (1/3)	5 (1/1)	-	-
Metribuzin 750 150 g (*metribuzin*)	Post-emergent	2008	-	✓ (1)	✓ (1)	-	-	-	-	-
Simazine 2 L + metribuzin 750 100-150 g plus 100 mL diflufenican (*simazine + metribuzin*)	Post-emergent	2012	✓ (1)	-	-	✓ (1)	✓ (1)	✓ (1)	-	-
Outlook® 1.0 L (*dimethenamid-P*)	Pre-seeding	2012-14	6 (1/3)	-	-	✓ (2)	✓ (1)	✓ (3)	-	-
Terbyne® 1.4 Kg (*terbuthylazine*)	Pre-seeding	2010-11	-	-	N (1/2)	✓ (1)	N (1/2)	-	-	-
Simazine 2 L fb Brodal® 200mL (*simazine fb diflufenican*)	Pre-seeding fb 2 leaves	2005-06,08-14	N (1/5)	✓ (2)	7 (1/6)	✓ (3)	8 (1/4)	N (1/3)	✓ (1)	✓ (2)
Simazine 2 L fb Sniper® 50 g (*simazine fb picolinafen*)	Pre-seeding fb 2 leaves	2005-06	✓ (2)	✓ (1)	✓ (2)	-	-		✓ (1)	✓ (2)
Simazine 2 L fb metribuzin 100-150 g plus 100 mL diflufenican (*simazine + metribuzin*)	Pre-seeding fb 2 leaves	2005-06, 08-14	7 (1/5)	N (1/2)	N (2/6)	N (1/3)	N (1/4)	✓ (3)	N (1/1)	12 (1/2)
Simazine 2 L fb Brodal® 100mL + Sniper® 33-50 g (*simazine fb diflufenican + picolinafen*)	Pre-seeding fb 4 leaves	2005-06	✓ (2)	✓ (1)	✓ (2)	-	-	-	✓ (1)	✓ (2)
Simazine 2 L fb Brodal® 100 mL + metribuzin 750 g (*simazine fb diflufenican + metribuzin*)	Pre-seeding fb 4 leaves	2005-06	✓ (2)	✓ (1)	✓ (2)	-	-	-	21 (1/1)	27 (1/2)
Simazine 2 L fb Brodal® 100 mL + metribuzin 750 150 g (*simazine fb diflufenican + metribuzin*)	Pre-seeding fb 4 leaves	2008-14	N (1/3)	✓ (1)	N (2/4)	N (1/3)	N (2/4)	N (2/3)	-	-
Simazine 2 L fb Sniper® 33-50 g + metribuzin 750 100 g (*simazine fb picolinafen + metribuzin*)	Pre-seeding fb 4 leaves	2005-06	✓ (2)	✓ (1)	✓ (2)	-	-	-	18 (1/1)	24 (1/2)
Simazine 2 L fb Brodal® 100 mL + Eclipse® 50 g (*simazine fb diflufenican + metosulam*)	From 8 leaf stage	2005-06, 08	✓ (3)	✓ (2)	✓ (3)	-	-	-	✓ (1)	✓ (2)
Simazine 2 L fb Sniper ® 33-50 g + Eclipse® 50 g (*simazine fb picolinafen + metosulam*)	From 8 leaf stage	2005-06	✓ (2)	✓ (1)	✓ (3)	-	-	-	✓ (1)	✓ (2)
Simazine 2 L fb Brodal® 100 mL + simazine 0.75-1 L (*simazine fb diflufenican + simazine*)	Pre-seeding fb 4 leaves	2005-06, 08-14	11 (1/5)	✓ (2)	7-10 (2/6)	✓ (3)	6 (1/4)	10 (1/3)	✓ (1)	✓ (2)
Simazine 2 L fb Brodal® 100, 150, 200 mL + Sniper® 33-50 g + simazine 0.75-1 L (*simazine fb diflufenican + picolinafen + simazine*)	Pre-seeding fb 4 leaves	2005-06	✓ (2)	✓ (1)	✓ (2)	-	-	-	✓ (1)	9 (1/2)
Simazine 2 L fb Brodal® 100 mL + metribuzin 750 100 g + simazine 0.75-1 L (*simazine fb diflufenican + metribuzin + simazine*)	Pre-seeding fb 6 leaves	2005-06, 08	✓ (2)	✓ (2)	✓ (3)	-	-	-	30 (1/1)	25 (1/2)

FEEDBACK

Herbicides (Rates/ha)	Timing	Year of Testing	Coromop®	Jenebillup®	Mandelup®	PBA Barlock®	PBA Gunyidi®	PBA Jurien®	Pootallong®	Tanjil®
Year of Testing and Trial sites			2005-06, 12-14 AB	2006, 08 B	2005-06, 08-11 AB	2011-13 A	2009-12 A	2012-14 A	2005 A	2005-06 AB
Simazine 2 L fb Sniper® 33-50 g + metribuzin 750 100 g + simazine 0.75-1 L (*simazine fb picolinafen + metribuzin + simazine*)	Pre-seeding fb 6 leaves	2005-06	✓ (2)	✓ (1)	✓ (2)	-	-	-	46 (1/1)	28 (1/2)
Simazine 2 L fb Brodal® 100 mL + Eclipse® 50 g (*simazine fb diflufenican + metosulam*)	From 8 leaf stage	2009-14	10 (1/3)	-	9 (1/3)	6-14 (2/3)	6-11 (2/4)	13 (1/3)	-	-
Simazine 2 L fb Eclipse® 50 g (*simazine fb metosulam*)	Pre-seeding fb 8 leaves	2009-14	12 (2/3)	-	N (1/3)	10 (1/3)	6-11 (2/4)	13 (1/3)	-	-
Eclipse® 7 g (*metosulam*)	From 8 leaf stage	2011	-	-	N (1/1)	N (1/1)	N (1/1)	-	-	-

The names in the parenthesis are the chemical names. fb =followed by. A= Eradu (Sandy to loamy sand, pH ($CaCl_2$): 4.2-6.2, OC: 0.45-1.05%, rainfall (May-Oct): 217 - 428 mm), B = Wongan Hills (Shallow duplex sandy to loamy sand, pH ($CaCl_2$): 4.6-4.9, OC: 0.7-0.9%, rainfall (May-Oct): 150-262 mm). Simazine, atrazine and diuron rates are based on their 500 formulations. Permit 14452 allows to use metribuzin 150 g a.i./ha pre-seeding in WA on Mandelup® and Coromup® varieties only. The permit is valid up to 30 June 2018. Higher than the label herbicide rates to work out crop safety margins (N) were not used for all the treatments.

Pootallong is a yellow lupin (*Lupinus lutenus L.*) variety released during 2005.

A narrow crop safety margin implies that when spraying herbicide at the label rate under less than optimal conditions, herbicide damage and yield loss may occur. For example, when:

- overlapping herbicide
- spraying under wet conditions (for soil active and residual herbicides)
- there are stressed plants due to abiotic/biotic factors.

Research site location	Eradu (A)	Wongan Hills (B) 2006, 08
Site soil type	Eradu Sandplain	Loamy sand
Site pH ($CaCL_2$)	5.5	4.6 - 4.9
Site annual average rainfall (mm)	374	

NOTES to table: Safe use of herbicides on lupin[4]

- Interaction of mouldboard ploughing with shallow seeding and soil-applied residual herbicides in lupin could cause crop damage.
- High uptake of pre-emergent simazine and/or atrazine following good soil moisture or high usage rates may predispose the lupin crop to damage by typically 'safe rates' of post-emergent broadleaf herbicides. Symptoms may include leaf whitening, root rot or Brown leaf spot.
- Diflufenican (e.g. Brodal®) and picolinafen (e.g. Sniper®) alone, or in combination with other herbicides, cause bleaching/leaf spotting on most of the lupin varieties. Symptoms typically outgrow with time.
- The use of metribuzin alone, or in combination with other herbicides, may cause leaf burn and slight crop suppression in most varieties. Maximum rate of metribuzin 750 registered for post-emergent use on lupin is 150 grams ai/hectare.
- It is advised to not apply metribuzin in mixture with other herbicides if Brown leaf spot or other leaf diseases are present.
- Metosulam (e.g. Eclipse®) often causes yellowing, height and/or biomass reduction in most of the lupin varieties. Plants typically recover rapidly in typical

4 Dhammu, Harmohinder, DAFWA (2017), harmohinder.dhammu@agric.wa.gov.au

growing conditions. It is advised not to use oils and wetters with metosulam and to apply only on healthy crops up to the visible bud stage.

- Broadleaf herbicides should not be mixed with oil or products containing emulsifying agents.
- Application of broadleaf post-emergent herbicides to moisture-stressed lupin, or at the likely onset of moisture stress soon after application, can lead to damage from herbicides that are typically 'safe' when used in typical growing conditions.
- All grass selective herbicides at label rates are typically safe when used on lupin, but it is advised not to apply such products in a tank mix with the broadleaf herbicides – as crop damage will result.
- Ensure at least a 10-day break between spraying broadleaf herbicides and a grass selective herbicide.

WA experience has shown that the newest albus lupin variety, Amira, has good tolerance of registered herbicides and mixes at recommended rates.

Some research shows that it appears to have a low crop safety margin for pre-emergent simazine use and some post-emergent mixes with simazine.

5.3 Managing residual herbicide issues

Lupin crops can be affected by herbicide residues where rainfall has been insufficient in both summer and the previous growing season.

Lupin has a particular sensitivity to Group B sulfonamide residues and, in high pHsoils, some sulfosulfuron active residues can create problems.

All pulses, including lupin, are vulnerable to Group I phenoxy residues (such as 2,4-Damine and MCPA), particularly in sandy soils with low rates of microbial breakdown.

Clopyralid is another Group I active that has shown significant residual effects in lupincrops the following season after summer application in some areas.

The Group I chlorophenoxy herbicide Dicamba can also be an issue if it is used in autumn prior to sowing lupin crops in some areas.

Other Group I amicide formulations tend to result in more residual issues than ester formulations in some regions and situations.

There may also be residue issues arising from the use of some newer herbicide options, such as the Group K metolachlor-prosulfocarb combination, Group C terbuthylazine and Group K dimethenamid, as outlined below.

5.3.1 Tips for managing newer herbicide options

It is recommended, if using the Group K and Group E metolachlor and prosulfocarb Boxer Gold® herbicide as a pre-emergent, to apply to soil surface up to seven days before sowing lupin crops and incorporate it mechanically through the seeding process.

Application should be into a moist seedbed and when the outlook is for sufficient rain to thoroughly wet the top 3-4 cm of soil within 10 days of application.

It is advised to use Boxer Gold®:

- In seeding systems that ensure accurate seed placement and adequate separation of seed and herbicide
- Soils not prone to waterlogging
- When there are no heavy rains likely to cause run-off forecast within two days of application.

More information about this herbicide can be found at: http://herbiguide.com.au/Descriptions/hg_Boxer_Gold.htm

MORE INFORMATION

Pulse Australia 'Residual Herbicides and Weed Control' hub: http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicidesHerbiGuide, Boxer Gold®: http://herbiguide.com.au/Descriptions/hg_Boxer_Gold.htm

HerbiGuide Sakura®: http://www.herbiguide.com.au/Descriptions/hg_Pyroxasulfone.htm

HerbiGuide Outlook®: http://www.herbiguide.com.au/Labels/DIMEP720_65695-63240.PDF

FEEDBACK

If using the Group K pyroxasulfone herbicide, Sakura® 850 WG, it is best appliedjust before sowing and incorporated by the seeding process using knife points andpress wheels (avoiding throwing treated soil into adjacent rows) or narrow pointsand harrows.

Note that Sakura® 850 WG can only be applied before sowing a lupin crop and lupin cannot be sown for nine months after this herbicide is used in situations such as a failed establishment of a wheat crop.

If using Sakura® 850 WG, it is advised to apply if:

- There is no heavy rain forecast within two days of application
- Incorporation with seeding can be achieved within three days of application
- Soil is not waterlogged.

It is advised not to use Sakura® where:

- Heavy rain has been forecast within 48 hours of application
- Incorporation by sowing (IBS) cannot be performed within three days of application
- There are waterlogged soils.

Other factors that may reduce weed control from Sakura® 850 WG include: uneven application; application to ridged or 'clodded' soils; high levels of stubble, plant residue or other ground cover; or if there is heavy rain on sandy soil types prone to leaching.

More information about Sakura® 850 WG is available at: http://www.herbiguide.com.au/Descriptions/hg_Pyroxasulfone

If considering the Group C herbicide terbuthylazine, apply to lupin as Terbyne® Xtreme® 875 WG, this is best used at the lower registered rate on lighter soils (such as sandy loams and loamy sands) and at higher registered rates on heavier soils (such as loams or silt-clay).

Best results will come from ensuring lupin seed is covered with 3-5 cm of soil at seeding and when there is sufficient rainfall (about 20-30 mm) within two or three weeks of application to wet the soil right through the weed root zone.

It is recommended to apply Terbyne® Xtreme®, if being considered for use in lupin crops, if there are no heavy rains forecast for two days, soils are not waterlogged and at rates less than 0.86 kilograms per hectare on soils with a pH of 8 or more.

The Group K herbicide dimethenamid-P, applied to lupin as Outlook®, controls annual ryegrass in low populations of typically less than 100 plants per square metre.

It will act to only suppress weeds in higher populations.

It is advised, if using, to apply this herbicide as late as possible before sowing and to use a knifepoint and press wheel system before weeds germinate. Weeds that are emerging, or emerge soon after application, are typically unlikely to be controlled, necessitating the use of a post-emergent knockdown.

FEEDBACK

MORE INFORMATION

GRDC 'Integrated Weed Management Manual': www.grdc.com.au/IWMM

GRDC 'Integrated Weed Management': www.grdc.com.au/Resources/IWMhub/

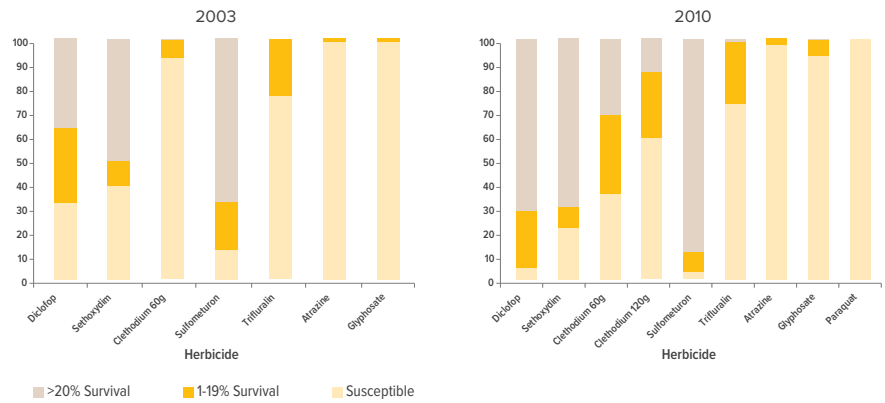
5.4 Importance of integrated weed management (IWM)

- Plan rotations in advance to minimise weed challenges
- Control weeds before or at sowing using physical, cultural and chemical methods
- Enable crops to compete strongly with weeds – using seeding rates, row spacing, nutrition
- Understand how to maximise herbicide efficacy
- Reduce seed set by weeds using crop-topping or desiccation
- Reduce the number of weed seeds in the paddock by using chaff carts, burning windrows left by headers, baling lupin straw or seed destruction/seeking technology.[5]

Adoption of IWM tactics is vital to sustaining long-term profitable cropping rotations in WA by achieving good weed control, helping to manage herbicide resistance and driving down weed seedbank numbers.

As shown in Figure 1, the incidence of annual ryegrass resistance to a range of herbicides in WA – as tracked through Australian Herbicide Resistance Initiative (AHRI) surveys – is high and increasing.

Figure 1: *A snapshot of annual ryegrass resistance to a range of herbicides in WA, highlighting changes from 2003 to 2010 surveys.*[6]



(SOURCE: AHRI)

Long-term WA 'Focus Paddock' trials – funded by the Grains Research and Development Corporation (GRDC) and carried out in conjunction with the Department of Primary Industries and Regional Development (DPIRD) – formerly the Department of Agriculture and Food Western Australia (DAFWA) – are demonstrating that it is possible to profitably crop at high intensity, while eroding the weed seedbank and in-crop weed numbers using an IWM approach. This is despite originally having high levels of herbicide resistance.[7]

In Focus Paddock trials from 2001 to 2013 in 31 central and northern grainbelt paddocks where IWM was used, annual ryegrass seedbank populations fell 96 percent from an average 183 annual ryegrass plants per square metre to only eight annual ryegrass plants/m^2. At the same time, an average cropping intensity of 89 percent was maintained.[8]

5 DPIRD (2016) Lupin Essentials – growing a successful lupin crop – weed control, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C3#smartpaging_toc_p3_s0_h2

6 DPIRD (2015) Focus Paddock Report, GRDC website, https://www.agric.wa.gov.au/grains-research-development/focus-paddocks-project-%E2%80%93-profitable-crop-and-pasture-sequencing

7 DPIRD (2015) Focus Paddock Report, GRDC website, https://www.agric.wa.gov.au/grains-research-development/focus-paddocks-project-%E2%80%93-profitable-crop-and-pasture-sequencing

8 DPIRD (2015) Focus Paddock Report, GRDC website, https://www.agric.wa.gov.au/grains-research-development/focus-paddocks-project-%E2%80%93-profitable-crop-and-pasture-sequencing

FEEDBACK

The Focus Paddock project highlighted the importance of harvest weed seed control (HWSC) in reducing weed populations as part of an IWM plan. It found growers who had the most success at managing annual ryegrass were those who practiced HWSC by towing a chaff cart and/or using narrow window burning. In the eighth year of using this practice, these growers had no annual ryegrass in their focus paddocks and have since averaged fewer than 1.5 ryegrass plants per square metre.[9]

WeedSmart, a GRDC and industry-funded herbicide sustainability initiative, has developed a 10 Point Plan for implementing IWM systems. This is available at the WeedSmart information hub (http://www.weedsmart.org.au/10-point-plan/) and outlines tips and tools for how to:

1. Act now to stop weed seed set
2. Capture weed seeds at harvest (HWSC)
3. Rotate crops and herbicide MOA
4. Test for resistance to establish a clear picture of paddock-by-paddock farm status
5. Aim for 100 percent weed control and monitor every spray event
6. Not automatically reach for glyphosate
7. Never cut the label herbicide rate, carefully manage spray drift and residues
8. Plant clean seed into clean paddocks with clean borders
9. Use the double-knock technique
10. Employ crop competitiveness to combat weeds.

DPIRD has produced a comprehensive IWM timeline for WA lupin crops, covering key weed control tactics and timing – from pre-sowing planning through to harvest. This can be seen in Table 3 and accessed online at this link http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins[10]

9 DPIRD (2015) Focus Paddock Report, GRDC website, https://www.agric.wa.gov.au/grains-research-development/focus-paddocks-project-%E2%80%93-profitable-crop-and-pasture-sequencing

10 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

FEEDBACK

Table 3: Weed Management Time Line

Weed Management Time Line	
PRE-SOWING	
Paddock selection	Target a low weed burden paddock. Less than 20 to 30 ryegrass plants/m^2 or less than 1 wild radish plant/m^2
Early herbicide application	Apply simazine on dry soil up to three weeks before sowing. Opening rains will incorporate simazine into the soil. Further incorporation by seeding after the break will ensure many weed seedlings will come in contact with the herbicide and be killed.
Variety selection	Use Mandelup□ for improved competition against weeds except where the risk from anthracnose is high.
Seed quality	Check germination percentage to ensure good crop emergence. Germination can be reduced by crop-topping, storage and handling conditions, moisture content at harvest, seasonal growing conditions, seed size and insect damage.
Clean seed	Only sow clean seed—do not introduce weed problems.
CROP ESTABLISHMENT	
Dry sowing	Only dry sow lupin into a paddock that has a very low weed burden. Simazine requires moisture to be most effective. Weed control after dry sowing is likely to be variable.
Wet sowing	Wet sowing provides more even germination of weeds and lupin. Wet sowing allows simazine to work more effectively.
Target crop density	Aim for 45 plants/m^2 to ensure the crop is competitive against weeds.
Row spacing – narrow row spacing (< 20 cm) – wide row spacing (> 20 cm)	Row spacing will influence crop competitiveness. Narrow rows ensure the crop is competitive against weeds due to higher plant densities. Use wide rows only if the paddock is very clean or shielded spraying is planned.
Pre-emergence weed control	If unsure of annual ryegrass numbers, use trifluralin. If using trifluralin in more than one cropping phase, consider resistance risk.
POST-EMERGENCE	
Insect pest management	Damage by Redlegged earth mites or Lucerne fleas can result in increased post-emergence herbicide uptake and damage to the crop. Damage by insects may make the crop less competitive.
POST-EMERGENCE BROAD-LEAFED WEED CONTROL	
2- to 6-leaf crop	Available options include simazine top-up; diflufenican (for example, Brodal® options); or picolinafen (Sniper®). Apply early as these options are most effective on small radish. Do not apply simazine to plants showing symptoms of simazine damage.
6-leaf crop	Use metribuzin in a mixture with diflufenican (for example, Brodal® options) on tolerant varieties. Mandelup□ and Coromup□ are the most tolerant varieties. Metribuzin is more effective on weeds and less damaging to the crop in the northern wheatbelt.
8-leaf to flower bud	Use metosulam (Eclipse®) for wild radish plants that have up to eight leaves or are about 20 cm in diameter. Wild radish that are resistant to Group B herbicides (for example, chlorsulfuron and triasulfuron) can also be resistant to metosulam.
POST-EMERGENCE GRASS WEED CONTROL	
Simazine top-up	Very limited benefit for grass weeds. Some late emerging or very small 1- to 2-leaf ryegrass may be controlled. Simazine has limited activity on larger grass weeds.

FEEDBACK

Weed Management Time Line	
Grass selective herbicides	Where herbicide resistance is not a problem, grass selective herbicides (Group A herbicides with a Fop or Dim chemistry) can be used. The most effective grass weeds herbicides are often strong rates of Dim herbicides. However, be sure to know the resistance status of your weeds and choose the most effective chemical. Lupin crops provide an important opportunity to manage brome grass with Group A grass selective herbicides. Do not mix post-emergence grass selective herbicides with broad-leafed herbicides because crop damage will occur.
FLOWERING	
No suitable selective weed control options	Herbicide application during flowering may result in flower loss and reduced yield.
Cut your losses	If weed numbers have exploded out of control this is the time to green or brown manure a failed lupin crop to maximise renovation benefits. When brown manuring, use a double knockdown strategy to ensure that none of the weeds set seed.
LEAF DROP	
50 percent leaf drop	Swathing will reduce seed set in ryegrass effectively, but will not control a high proportion of seed set in radish. Yield losses can occur when picking up swaths. Swathed lupin should be harvested as soon as possible.
80 percent leaf drop	Crop-topping will reduce seed set in annual ryegrass, but often will not control a high proportion of seed set in radish. Yield losses of 5 percent are common. Do not keep seed from topped areas because viability may be reduced.
HARVEST	
Timing	Harvest as early as possible before weed seeds fall to the ground.
Residue management	Catch or minimise spread of weed seed by using chaff carts or by concentrating residues in windrows (narrow header trails) for burning in autumn.

(SOURCE: DAFWA)

Crop competition and orientation are emerging as key non-herbicide weed control measures in WA and can be used in lupin crops to reduce weed burdens.

Research has shown that as crop density increases, crop biomass increases and weed growth and weed seed set fall due to crops out-shading and out-competing weeds for water and nutrients. The challenge is to achieve this in a practical and cost effective way.[11]

11 Borger, C (2015) East-west orientation for improved crop competition, DAFWA, https://www.agric.wa.gov.au/grains-research-development/east-west-orientation-improved-crop-competition

FEEDBACK

MORE INFORMATION

GRDC Summer Fallow Weed Management Guide: www.grdc.com.au/GRDC-Manual-SummerFallowWeedManagement

GRDC Hot Topic 'Summer fallow weed management': www.grdc.com.au/Media-Centre/Hot-Topics/Summer-fallow-weed-management

5.5 Summer weed control

Figure 2: *Summer weeds are a scourge of WA lupin crops.*

(SOURCE: © Western Australian Agriculture Authority (Department of Agriculture and Food, WA))

- Conserves soil moisture and nutrients for crop use
- Reduces the need for high rates of herbicide knockdown before seeding
- Better controls large taproot species in knife point cultivation sowing systems
- Reduces risks of seeding delays
- Reduces weed allelopathic effects (such as toxin secretion) and can boost lupin emergence.[12]

The major summer weeds of WA cropping systems are:

- Flaxleaf fleabane (*Conyza bonariensis*)
- Windmill grass (*Chloris truncata*)
- Caltrop (*Tribulus terrestris*)
- Paddy melon (*Cucumis myriocarpus*)
- Afghan melon (*Citrullus lanatus*).

Growth rates of these weeds after summer rain are high and control in early stages of development is typically more reliable and cost effective than waiting until they are more robust plants.

Simazine (Group C) can be applied for control of most summer grass and broadleaf weeds (except taproot species) in lupin crops in February/March with little loss up until May. Registered rates of simazine (600 grams per Litre) are 830 millilitres per hectare to 1.7 L/ha on light soils and 1.7-2.5 L/ha on gravelly-loam soils.[13]

Research and experience in parts of WA has found some weeds, such as fleabane, can only be adequately controlled in summer using a well-timed double-knock.

This is typically a full registered rate of glyphosate (Group M) followed by a full label rate of paraquat (Group L). But this adds pressure to spray all paddocks in a timely manner and increases weed control costs.

12 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

13 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

Group B herbicides cannot be used for summer weed control on paddocks that will be sown to lupin due to the re-cropping interval. It is advised to always check the label before applying herbicides to lupin crops.

5.6 Grass weed control in lupin

5.6.1 Annual ryegrass (*Lolium rigidum*)

Figure 3: *Annual ryegrass in a WA cereal crop.*

(SOURCE: © Western Australian Agriculture Authority (Department of Agriculture and Food, WA))

- Highly competitive as early as two-leaf stage
- Can cause lupin yield losses of 5 percent for every 25 annual ryegrass plants/m^2
- Late sown crops affected more by weed competition
- Can produce up to 45,000 seeds/plant in ideal conditions
- About 80 percent seed germination after season break
- Several waves of germination typically make control difficult
- Can carry crop root diseases between seasons and years
- Harvest costs may increase due to seed contamination
- Increasing levels of resistance to Group A and B herbicides in WA
- Multiple herbicide resistance to some selective/non-selective herbicides in WA
- The most documented glyphosate-resistant populations of all WA weeds
- Low resistance to atrazine (Group C) and trifluralin (Group D) in WA
- HWSC can be effective, as seed is retained at harvest height.[14,15]

MORE INFORMATION

GRDC update paper 'Managing clethodim resistant ryegrass': www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Herbicides-for-control-of-clethodim-resistant-annual-ryegrass

GRDC update Paper 'Why the obsession with the ryegrass seedbank': www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Why-the-obsession-with-the-ryegrass-seed-bank

HerbiGuide, Annual Ryegrass: http://www.herbiguide.com.au/Descriptions/hg_Annual_Ryegrass.htm

DPIRD 'Lupin weed control': www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop

Ryegrass Integrated Management (RIM) model: www.ahri.uwa.edu.au/RIM

14 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

15 HerbiGuide website, Annual Ryegrass, http://www.herbiguide.com.au/Descriptions/hg_Annual_Ryegrass.htm

FEEDBACK

Management and control

Table 4: Tactics to consider when developing an integrated plan to manage annual ryegrass[16]

Annual ryegrass (*Lolium rigidum*)		Most likely % control (range)	Comments on use
Agronomy	Improve crop competition	50 (20–80)	Optimum sowing rates essential. Row spacing >250 mm to reduce crop competitiveness. Sow on time.
Tactic	Burning residues	50 (0–90)	Avoid grazing crop residues. Use a hot fire back-burning with a light wind.
Tactic	Inversion ploughing	95 (80–99)	Bury seed greater than 100 mm deep. Use of skimmers on the plough is essential for deep burial.
Tactic	Autumn tickle	15 (0–50)	Only effective on last year's seedset. Use in conjunction with delayed sowing.
Tactic	Fallow and pre-sowing cultivation	60 (0–90)	Cultivation may lead to increased annual ryegrass in the crop. Use in combination with a knockdown herbicide. Use cultivators that bury seed.
Tactic	Knockdown (non-selective) herbicides for fallow and pre-sowing control	80 (30–95)	Avoid overuse of the one herbicide MOA group. Wait until annual ryegrass has more than 2 leaves.
Tactic	Double knockdown or 'double-knock'	95 (80–99)	Reduces the likelihood of glyphosate resistance. Use glyphosate followed by paraquat or paraquat + diquat 3 to 10 days later.
Tactic	Pre-emergent herbicides	70 (50–90)	Note incorporation requirements for different products and planting systems.
Tactic	Selective post-emergent herbicides	90 (80–95)	Apply as early as possible after the annual ryegrass has 2 leaves to reduce yield losses in cereals.
Tactic	Spray-topping with selective herbicides	80 (60–90)	Apply before milk dough stage of annual ryegrass.
Tactic	Crop-topping with non-selective herbicides	70 (50–90)	Note stage of crop compared to stage of annual ryegrass. Often not possible to achieve without crop yield loss. Most likely to occur with quick finish to season.
Tactic	Pasture spray-topping	80 (30–99)	Graze heavily in spring to synchronise flowering.
Tactic	Silage and hay – crops and pastures	80 (50–95)	Most commonly used where there is a mass of resistant annual ryegrass growth. Follow up with herbicides or heavy grazing to control regrowth.
Tactic	Manuring, mulching and hay freezing	90 (70–95)	Most commonly used where there is a mass of resistant annual ryegrass growth. Follow up with herbicides or heavy grazing to control regrowth.
Tactic	Grazing – actively managing weeds in pastures	50 (20–80)	Graze heavily in autumn to reduce annual ryegrass plant numbers. Graze heavily in spring to reduce seedset.
Tactic	Weed seed collection at harvest	65 (40-80)	Best results when crop is harvested as soon as possible before ryegrass lodges or shatters.
Tactic	Sow weed-free seed	85 (50-99)	Reduces the risk of introducing resistant annual ryegrass to the paddock with crop seed.

(SOURCE: GRDC)

16 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

FEEDBACK

Past research in WA has highlighted the importance of early weed control for annual ryegrass. The most effective double-knock interval between glyphosate and paraquat application has been found to be between two and 10 days for seedling annual ryegrass plants.[17]

At sowing, research has found increasing crop seeding rate and banding fertiliser below the lupin seed can improve lupin plant competition and help to reduce annual ryegrass establishment and seed set. A target plant density of 40-45 plants/m^2 is recommended for narrow leafed lupin crops to be competitive with annual ryegrass and to optimise yield potential, but this will vary widely between locations and seasons.

Using narrow row spacings (25 cm) has been found to improve weed control in lupin crops grown in WA's cooler, longer-season environments (such as the Lakes district and southern regions).[18]

Pre-emergent herbicides registered for use to control annual ryegrass in WA lupin crops are:

- Atrazine (Group A) – suppression only
- Simazine (Group C)
- Diuron (Group C)
- Trifluralin (Group D) – suppression only
- Pendimethalin (Group D)

Tips for pre-emergent herbicide applications in WA lupin crops include:

  - Label rate of simazine (600 g/kg) for WA lupin is 830 mL/ha to 1.7 mL/ha (light soil) and 1.7-2.5 mL/ha (loam soil)
  - Avoid simazine on deep white, grey/gritty sands
  - On yellow sandplain soils, crop damage from simazine formulation can occur at 1.25 L/ha
  - Trifluralin can be added if grass weeds are expected.
  - To manage resistance issues, try not to use trifluralin in multiple crops in the rotation.[19]

Post-emergent herbicides registered for use to control annual ryegrass in WA lupin crops are:

- Haloxyfop (Group A)
- Clethodim (Group A)
- Sethoxydim (Group A)
- Butroxydim (Group A)
- Diclofop (Group A)
- Fluazifop (Group A)
- Quizalofop (Group A)
- Propaquizafop (Group A)
- Paraquat (Group L).)

17 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

18 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

19 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

Tips for post-emergent herbicide applications to control annual ryegrass in WA lupin crops include:

- Spray small weeds early
- Grass weeds need to be actively growing
- Avoid spraying weeds stressed by dry soil, cold weather or frost
- Use the highest registered label rate
- Use the recommended adjuvant
- Do not mix grass-selective and broadleaf herbicides
- If applying paraquat during the season and/or to crop-top, use before weed seed set
- Crop-topping with selective herbicides may be effective and economic
- Test and monitor herbicide resistance status of annual ryegrass.[20]

5.6.2 Wild oats (*Avena sativa* ssp. *Fatua* and *A. ludoviciana*)

Figure 4: *Group A resistant wild oats on the inter-row of wheat.*

(SOURCE: GRDC)

- Highly competitive – as early as two-leaf stage
- Produce up to 20,000 seeds/m^2 if uncontrolled
- About 40 percent of seed germinates at season break
- Another 10-30 percent germinates later in the season
- Seedbank can be depleted by 75 percent per year with good control
- Minimum tillage, narrow row crop spacing and banded fertiliser boost crop competition
- Seed catching at harvest is only partially effective
- In early harvested crops, up to 75 percent of seed is typically captured
- In late harvested crops, very few seeds are caught
- Harvesters can spread seed up to 250 metres from the parent plant
- Burning windrows/paddocks pre-sowing can destroy seed on the soil surface and reduce seed dormancy
- Host for Cereal cyst nematode (*Heterodera avenae*) and the Root lesion nematode (RLN) *Pratylenchus neglectus*
- Poor host of the RLN *P. thornei*.[21,22]

MORE INFORMATION

GRDC IWM hub 'Control of wild oats': https://grdc.com.au/Resources/IWMhub/Section-8-Profiles-of-common-weeds-of-cropping/Wild-oats

GRDC Ute guide 'Wild oats': www.grdc.com.au/Resources/Ute-Guides/Weeds/Grass/West/Wild-oats

GRDC Podcast 'Controlling wild oats': https://grdc.com.au/Media-Centre/GRDC-Podcasts/Southern-Weekly-Update/2015/10/103-south

HerbiGuide, 'Wild Oats': www.herbiguide.com.au/Descriptions/hg_Wild_Oat.htm

20 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

21 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

22 HerbiGuide website, Wild Oats, http://www.herbiguide.com.au/Descriptions/hg_Wild_Oat.htm

FEEDBACK

Management and control of wild oats

Table 5: Tactics that should be considered when developing an integrated plan to manage wild oats[23]

Wild oats (*Avena* spp.)		Most likely % control (range)	Comments on use
Agronomy	Crop choice and sequence	95 (30–99)	Summer crop–winter fallow rotation is very effective; numbers build up in winter pulse crops. Maintaining a clean winter fallow is the key to success.
Agronomy	Improve crop competition	70 (20–99)	Competitive crops at optimum sowing rates are very effective. High levels of control are achieved with barley, much lower with wheat.
Agronomy	Herbicide tolerant crops	90 (80–99)	Good to excellent control achieved with glyphosate resistant and triazine tolerant crops.
Tactic	Autumn tickle	40 (30–60)	Needs an break to season. Combine with delayed sowing.
Tactic	Delayed sowing	40 (30-60)	Must be used with an autumn 'tickle'.
Tactic	Knockdown (non-selective) herbicides for fallow and pre-sowing control	80 (70–90)	Wait until youngest plants have 2 leaves if possible. Late germinations will not be controlled.
Tactic	Pre-emergent herbicides	80 (70–90)	Works best when combined with competitive crops
Tactic	Selective post-emergent herbicides	80 (70–90)	Test for resistance before spraying. Use in combination with competitive crops.
Tactic	Spray-topping with selective herbicides	90 (60–99)	Flamprop methyl is very effective on flamprop susceptible wild oats. Best results with competitive crops, warmer conditions and at very early jointing stage of wild oats. Group Z resistance is common in many areas.
Tactic	Pasture spray-topping	80 (70–90)	Graze or spray survivors. Hay freezing works well.
Tactic	Silage and hay – crops and pastures	97 (95–99)	Harvest when wild oats are flowering. Control regrowth.
Tactic	Grazing – actively managing weeds in pastures	75 (60–80)	Graze heavily and continuously in spring.
Tactic	Weed seed collection at harvest	70 (20–80)	Works well on early harvested crops before wild oats drop their seeds.
Tactic	Sow weed-free seed	95 (0-100)	Only sow seed produced in wild oat-free paddocks.
Tactic	Clean farm machinery and vehicles	80 (0-100)	Ensure harvesters are well cleaned before moving to clean property or paddock.

(SOURCE: GRDC)

23 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

It is advised to plant weed seed-free crop and pasture seed, use clean tillage and harvesting machinery and clean any imported hay/grain for livestock to keep paddocks clean.

Controlling wild oats early in the season will maximise lupin yields.

A knockdown herbicide, such as a full label rate of glyphosate, followed five to seven days later with a full label rate of paraquat and use of minimum tillage can set up lupin paddocks well.

Pre-emergent herbicides registered for use in wild oats in WA lupin crops are:

- Simazine (Group C) – registered for suppression only
- Atrazine (Group C) – registered for suppression only
- Triallate (Group J).

Post-emergent selective herbicides registered for use in wild oats in WA lupin crops are the Group A actives fluazifop-P and butroxydim.

Tips for post-emergent herbicide applications to help control wild oats in WA lupin crops include:

- » Apply top-up N before post-emergence spraying
- » Group A herbicides (Fops and Dims) usually provide best in-crop control
- » Repeated herbicide use may lead to resistance
- » Rotation with triallate + trifluralin can help delay resistance.[24]

MORE INFORMATION

DPIRD: https://www.agric.wa.gov.au/grains-research-development/management-brome-grass-bromus-spp

HerbiGuide, Brome grass: www.herbiguide.com.au/Descriptions/hg_Great_Brome.htm

5.6.3 Brome Grass (*Bromus diandrus; B. diandrus rigidus* – previously known as *B. rigidus*)

Figure 5: *An illustration of Fop and Dim resistant brome grass that has died-off when first sprayed, but recovered to produce new tillers.*

(SOURCE: GRDC)

- Widespread across the WA grainbelt
- Highly competitive with crops
- More aggressive than annual ryegrass, barley grass or silver grass
- Tolerant to drought and phosphorus (P) deficiency
- Responds rapidly to N fertiliser applied in-crop
- Produces high numbers of seeds (600-3000 per plant)
- Host for nematodes and cereal diseases
- Declining use of some Group A and B herbicides in WA (as other weed species have developed widespread resistance)
- Confirmed resistance to sulfonylureas (Group B) herbicides in six WA populations
- Resistance to Group A herbicides (Fops and Dims) in one population
- Resistance to glyphosate (Group M) confirmed in WA (a red brome population)
- Most seeds shed before harvest, so HWSC not highly effective.[25,26]

24 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

25 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

26 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

Management and control of brome grass

Table 6: Tactics to consider when developing an integrated plan to manage brome grass[26]

Brome grass (*Bromus* spp.)		Most likely % control (range)	Comments on use
Tactic	Burning residues	70 (60–80)	Sufficient crop residues are needed.
Tactic	Autumn tickle	50 (20–60)	Depends on seasonal break. Seed burial through shallow cultivation enhances seed depletion through germination, especially in *B. diandrus* with its shorter dormancy and faster germination.
Tactic	Delayed sowing	70 (30–90)	Best results with early seasonal break.
Tactic	Fallow	80 (70-90	Start the chemical fallow before weeds set seed (i.e. early spring).
Tactic	Knockdown non-selective herbicides for fallow and pre-sowing control	80 (30–99)	If possible delay spraying until full emergence and youngest plants have 2 leaves.
Tactic	Pre-emergent herbicides	80 (40–90)	Follow label directions, especially on incorporation requirements of some herbicides.
Tactic	Selective post-emergent herbicides	90 (75–99)	Apply when weeds have 2 to 6 leaves and are actively growing.
Tactic	Pasture spray-topping	75 (50–90)	Spray before viable seedset. Respray or graze survivors. Use this technique 2 years before going back to crop.
Tactic	Silage and hay – crops and pastures	60 (40–80)	Silage is better than hay. Graze or spray regrowth.
Tactic	Manuring, mulching and hay-freezing	90 (75-95)	Manuring works well if done before seed set. Any regrowth must be controlled.
Tactic	Grazing – actively managing weeds in pastures	50 (20–80)	Graze infested areas heavily and continuously in winter and spring.
Tactic	Weed seed collection at harvest	70 (10–75)	Works best on early harvested crops before weeds drop their seeds

Lupin crops can provide a better opportunity to control brome grass than cereal crops, as there are more herbicide options available.

Preventing seed set later in the season with mowing, cultivation and/or burning windrows/paddocks can be effective in reducing the brome grass seedbank in the longer term.

Despite AHRI herbicide resistance surveys finding WA brome grass populations with resistance to some Group A, B and M herbicides, a range of pre and post-emergent options are still available to control this weed.

Crop-topping with glyphosate in lupin crops may also reduce brome grass seed set. Timing is the main issue to consider, as brome grass matures a lot faster than some crops and will set seed before the crop can be legally sprayed.

Lupin crops typically mature early enough to kill many grass weeds by crop-topping, but this will require using an early maturing crop variety and sowing early.[27]

The Group C pre-emergent herbicides simazine and atrazine are registered for suppression of brome grass in WA lupin crops.

27 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

Post-emergent herbicides registered to help control brome grass in WA lupin are:

- Clethodim (Group A)
- Butroxydim (Group A)
- Fluazifop (Group A)
- Haloxyfop (Group A)
- Quizalofop (Group A)
- Propaquizafop (Group A).

5.6.4 Barley grass (*Hordeum glaucum* and *H. leporinum*).

Figure 6: *Barley grass can be a source of stripe rust disease in grain cropping and pasture areas of WA.*

(SOURCE: GRDC)

- Germinates rapidly in autumn
- Group A herbicides typically provide good control in lupin
- Some WA populations have resistance to Group B (SU) herbicides (such as sulfometuron and sulfosulfuron)
- Other states have barley grass with resistance to paraquat and diquat; several Group A Fops; and cross resistance to the Group A Dim herbicides.[28]

MORE INFORMATION

DPIRD 'Barley grass': https://www.agric.wa.gov.au/grains-research-development/barley-grass

HerbiGuide, 'Barley Grass': http://www.herbiguide.com.au/Descriptions/hg_Barley_Grass.htm

28 DPIRD (2016) Barley Grass, https://www.agric.wa.gov.au/grains-research-development/barley-grass

FEEDBACK

Management and control of barley grass

Table 7: Tactics to consider when developing an integrated plan to manage barley grass[29]

Barley grass (*Hordeum* spp.)		Most likely % control (range)	Comments on use
Agronomy	Crop choice and sequence	85 (0-95)	Avoid planting barley in infested areas.
Agronomy	Herbicide tolerant crops	80 (40-95)	Triazines and imidazolinone herbicides provide useful control in triazine and imidazolinone tolerant crops respectively.
Tactic	Burning residues	50 (0–75)	Dropping chaff and straw into windrows improves control.
Tactic	Inversion ploughing	90 (70–99)	Use skimmers to ensure deep burial.
Tactic	Delayed sowing	60 (50–90)	Level of control depends on break.
Tactic	Fallow and pre-sowing cultivation	50 (30–80)	Requires dry weather following cultivation.
Tactic	Knockdown (non-selective) herbicides for fallow and pre-sowing control	80 (50–90)	Works best if delayed until the 2- to 4-leaf stage after good opening rains.
Tactic	Double knockdown or 'double-knock'	80 (60–95)	Works best if delayed until the 2- to 4-leaf stage after good opening rains.
Tactic	Pre-emergent herbicides	85 (75–99)	Pyroxasulfone provides good control in wheat.
Tactic	Selective post-emergent herbicides	90 (80–95)	Several Fop herbicides provide good control in broadleaf crops. Sulfosulfuron provides suppression in wheat.
Tactic	Crop-topping with non-selective herbicide	80 (50–90)	Timing is aimed at maximising weed seed kill and minimising effect on the crop.
Tactic	Pasture spray-topping	60 (50–90)	Graze heavily or winter-clean with Fop herbicides to induce more uniform emergence of heads. Timing is critical. Graze or spray regrowth.
Tactic	Silage and hay – crops and pastures	50 (30–80)	Silage provides better control than hay making. Heavily graze or spray regrowth.
Tactic	Manuring – green and brown, mulching and hay freezing	75 (50–90)	Graze heavily to induce more uniform emergence of heads. Timing is critical. Graze or spray regrowth.
Tactic	Grazing – actively managing weeds in pastures	30 (0–50)	Use high stocking rates early in the season to reduce numbers, and late in the season to reduce seedset on infested paddocks.

(SOURCE: GRDC)

29 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

Simazine and atrazine (Group C actives) are pre-emergent herbicide options to help control barley grass in WA lupin crops, although atrazine is registered for suppression only.

Post-emergent herbicide options to help control barley grass in WA lupin are:

- Clethodim (Group A)
- Butroxydim (Group A)
- Fluazifop (Group A)
- Haloxyfop (Group A)
- Quizalofop (Group A)
- Propaquizafop (Group A).

MORE INFORMATION

DPIRD 'Silver grass' hub: https://www.agric.wa.gov.au/grains-research-development/silver-grass?page=0%2C1

5.6.5 Silver grass (*Vulpia myuros* and *V. bromoides*)

Figure 7: *Silver grass can reduce lupin crop yields when at high densities.*

(SOURCE: Agronomo)

- Can severely reduce crop yields when at high densities
- A host for diseases and pests, including cereal root diseases, webworm and some RLNs
- No confirmed cases of herbicide resistant silver grass in WA
- There are cases of paraquat resistance in other states
- Many herbicides provide suppression, rather than control, of silver grass
- Some herbicides only control surface-germinating seeds (always check the herbicide label)
- Seed has little dormancy, making early control of the initial flush of germination highly effective.[30]

30 DPIRD (2016) Silver Grass, https://www.agric.wa.gov.au/grains-research-development/silver-grass

FEEDBACK

Management and control of silver grass

Table 8: Tactics to consider when developing an integrated plan to manage silver grass[31]

Silver grass (*Vulpia* spp.)		Most likely % control (range)	Comments on use
Agronomy	Crop choice and sequence	80 (70–95)	Rotate to a triazine tolerant or glyphosate resistant canola in heavily infested areas.
Agronomy	Herbicide tolerant crops	95 (90–99)	Using pre- and post-emergent applications of triazine herbicide in triazine tolerant crops will almost eradicate most species of *Vulpia*.
Agronomy	Improve pasture competition	Variable	Reduces seed production, helping to maintain a low incidence of silver grass in a pasture. Winter clean with simazine.
Tactic	Burning residues	50 (30–70)	Use a hot fire back-burning into the wind.
Tactic	Inversion ploughing	90 (80–99)	Use a plough with skimmers to bury seed more than 75 mm deep.
Tactic	Autumn tickle	60 (50–80)	Requires an early break to the season. Combine with delayed sowing.
Tactic	Delayed sowing	75 (50–90)	Works well in most seasons. Tends to fail on non-wetting soils.
Tactic	Fallow and pre-sowing cultivation	70 (50–90)	Generally works well. Crop using full soil disturbance with late sowing to enable use of knockdown herbicides plus cultivation.
Tactic	Knockdown (non-selective) herbicides for fallow and pre-sowing control	Up to 95%	Ensure good herbicide coverage.
Tactic	Double knockdown or 'double-knock'	80 (70–95)	If this is required, pasture cleaning or spray-topping should have occurred 2 years before cropping.
Tactic	Pre-emergent herbicides	80 (70–95)	Triazines are very good on most species of *Vulpia*.
Tactic	Selective post-emergent herbicides	Up to 95%	If silver grass is the main component of the pasture there will be a loss of winter fodder. The treated pasture should be resown in the following season or renovated to increase the component of desirable species.
Tactic	Pasture spray-topping	Up to 85%	Timing is critical. Heavy grazing leading up to topping will induce uniform head emergence. Gives the ability to keep desirable pasture species while reducing the incidence of silver grass. Conduct two seasons before cropping.
Tactic	Silage and hay – crops and pastures	Up to 90%	Cut for silage at commencement of flowering. Control regrowth.
Tactic	On-farm hygiene	Variable	Contaminated hay should not be moved to clean areas.

(SOURCE: GRDC)

Simazine is the registered pre and post-emergent herbicide option for control of silver grass in WA lupin crops. The other Group C active, atrazine, can be used for suppression in lupin.

31 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

5.7 Broadleaf weed control in lupin

5.7.1 Wild radish (*Raphanus raphanistrum*)

Figure 8: *Wild radish is one of the most widespread weeds in WA and can cause losses in lupin yields through competition.*

(SOURCE: GRDC)

- One of the most widespread and competitive broadleaf weeds in Australia
- Can cause yield losses of 10-90 percent in WA lupin crops
- A prolific seeder with high seedbank dormancy
- Up to 70 percent of seeds still dormant in the next cropping season
- More than 90 percent of populations in WA resistant to one or multiple herbicides
- High resistance to some Group B and Group I herbicides (sulfonylureas, sulfonamides and phenoxy)
- Populations with resistance to some Group F and C herbicides
- Resistance to glyphosate found in WA in 2013
- Triazines still effective in the majority of WA paddocks, but resistance becoming widespread
- Important to kill in-crop weeds while small – less than 20 cm diameter
- Seeds become viable within three weeks of first flowers
- Retains seed pods at harvest height, making HWSC effective
- Long-term management requires driving seed numbers down to low levels
- Hand picking of resistant plants in-crop is being evaluated in parts of WA.[32,33]

MORE INFORMATION

GRDC Fact Sheet 'Wild radish': www.grdc.com.au/GRDC-FS-WildRadishManagement

GRDC Hot Topic 'Wild radish control options in WA': www.grdc.com.au/Media-Centre/Hot-Topics/Wild-radish-control-options-in-WA

GRDC 'Herbicide resistance testing': www.grdc.com.au/Media-Centre/Media-News/South/2014/04/Herbicide-resistance-testing-autumn-2014

DPIRD 'Wild radish': https://www.agric.wa.gov.au/grains-research-development/wild-radish

32 DPIRD (2016) Wild Radish, https://www.agric.wa.gov.au/grains-research-development/wild-radish

33 GRDC (2014) Fact Sheet – Wild radish, www.grdc.com.au/GRDC-FS-WildRadishManagement

FEEDBACK

Management and control of wild radish

Table 9: Tactics to consider when developing an integrated plan to manage wild radish[34]

Wild radish (*Raphanus raphanistrum*)		Most likely % control (range)	Comments on use
Agronomy	Herbicide tolerant crops	90 (80–99)	If growing canola in a crop sequence with lupin in a wild radish infested area it is essential to use a herbicide resistant variety and associated herbicide package.
Tactic	Burning residues	70 (20–90)	In concentrated windrows. Burn when conditions are conducive to a hot burn.
Tactic	Inversion ploughing	98 (20-100)	Plough must be correctly 'set up' and used under the right conditions. Must use skimmers.
Tactic	Autumn tickle	45 (15–65)	Follow-up rain is needed for better response.
Tactic	Knockdown (non-selective) herbicides for fallow and pre-sowing control	80 (70–90)	Add a reliable herbicide spike for more reliable control. Late germinations will not be controlled.
Tactic	Selective post-emergent herbicides	90 (70–99)	Apply to young and actively growing weeds. Repeat if necessary to control late emerging weeds or survivors.
Tactic	Spray-topping with selective herbicides	80 (70–95)	Wild radish may regrow if there are late rains. Good for seedset control. Spray before embryo development for best results.
Tactic	Wiper technology	70 (50–80)	Has potential in low growing pulses such as lentils.
Tactic	Silage and hay – crops and pastures	80 (70–95)	Cut before embryo formation in developing wild radish seed (21 days after first flower). Graze or spray regrowth.
Tactic	Manuring, mulching and hay freezing	95 (90–100)	Brown manuring more efficient than green manuring and more profitable. Grazing before spraying to open sward will improve results. Hay freezing works well and is the most profitable manuring option in most cases.
Tactic	Grazing – actively managing weeds in pastures	70 (50–80)	Rotationally graze and use spray-grazing. Can also use slashing to improve palatability and reduce pasture growth rate in spring.
Tactic	Weed seed collection at harvest	75 (65–85)	Most reliable in early harvested paddocks.
Tactic	Sow weed-free seed	95 (90-100)	Very important as resistance in wild radish is increasing and introduction via crop seed is increasingly likely.

(SOURCE: GRDC)

34 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

High seed dormancy and increasing levels of herbicide resistance make wild radish difficult to control in WA lupin crops, which are also poor competitors with this weed.

Lowering the wild radish seedbank can take up to 10 years, as any plants that survive one season to set seed will replenish the soil with a new wave of dormant seed that can take up to 18 months to germinate.[35]

Effective control of this weed requires an integrated approach involving:

- Testing seed from surviving wild radish plants at harvest for herbicide resistance
- Application of glyphosate and/or paraquat during summer at full label rates
- Narrow row spacing or paired rows at seeding to boost crop competition
- Harvest weed seed capture and destruction
- Weed detection technology, if cost effective
- Use of decision-support tools, such as Weed Seed Wizard.[36]

In recent years, there has been a sharp increase in levels of wild radish resistance to commonly used herbicides for control of this weed in WA.

The 2010 AHRI herbicide resistance surveys for wild radish in WA found:

- 84 percent contained plants resistant to chlorsulfuron (Group B) – up 30 percent from 2003 levels.
- 49 percent were resistant to Intervix (Group B)
- 76 percent were resistant to 2,4-D amine
- 49 percent were resistant to Brodal® (Group F)
- One population had atrazine resistant plants.[37]

Wild radish control in WA is heavily dependent on the use of simazine (Group C) pre-emergent herbicides, with a post-emergent mix of diflufenican (Group F) and metribuzin.

Key challenges for growers have been wild radish populations with multiple resistance to simazine and diflufenican, which has reduced the effectiveness of these herbicides.

Wild radish with resistance to sulfonylureas (Group B) herbicides has also become widespread.[38]

The release of lupin varieties PBA Leeman, PBA Jurien in 2016 and PBA Barlock in 2013 are seen as positive steps in improving control of weeds for the WA lupin industry.

These varieties have enhanced tolerance of the herbicide metribuzin (higher than Tanjil and equal to PBA Mandelup) and resistance to the disease anthracnose.

Triazine herbicides (Group C – including simazine and atrazine) remain highly effective in controlling wild radish in lupin crops.

To maximise effectiveness and longevity of these herbicide MOAs, it is advisable to sow crops when the soil is wet after the break and use varieties with good triazine tolerance, such as PBA Leeman , PBA Jurien, PBA Barlock, Mandelup and PBA Gunyidi.

Research in WA's northern agricultural region in 2012-13 found a two-spray strategy for wild radish increased lupin yields by 0.4-0.5 t/ha on average – and up to 1 t/ha at some sites – compared to untreated weeds. The first treatment was a full label rate of a Group C or F herbicide at the weed two-leaf stage (less than 20 cm in diameter),

35 GRDC (2014) Fact Sheet – Wild radish, www.grdc.com.au/GRDC-FS-WildRadishManagement

36 DPIRD (2016) Wild Radish, https://www.agric.wa.gov.au/grains-research-development/wild-radish

37 Australian Herbicide Resistance Initiative (2015) Wild Radish Surveys, The University of Western Australia, http://ahri.uwa.edu.au/research/surveys/wild-radish/

38 Australian Herbicide Resistance Initiative (2015) Wild Radish Surveys, The University of Western Australia, http://ahri.uwa.edu.au/research/surveys/wild-radish/

followed by a second full rate application of an alternative herbicide MOA at the weed five-leaf stage.[39]

Research trials have shown for every one wild radish plant/m^2, lupin yields fall by an average of 5 percent in most WA grainbelt areas.[40]

Wild radish reduces lupin yields by decreasing pod number, grain size and germination rates.

Increasing lupin crop density to a target of 50 plants/m^2 has been found to reduce the adverse yield effects of this weed.[41]

WA research has demonstrated that increased lupin crop density and competition with wild radish can be achieved by a combination of:

- High seeding rates of about 100 kg/ha
- Narrow row spacing of 17-25 cm
- Paired row spacing of 7.5 cm
- Using east-west sowing row orientation.[42]

Existing machinery can be modified for paired-row seeding so that the tyne spacing best for stubble handling and sowing speed can stay the same.

Growers in WA's northern agricultural area, in particular, have been able to drive wild radish seedbank numbers to very low levels using a range of these mechanical, cultural and herbicide IWM tactics.

Researchers in this region are now investigating the cost effectiveness and thresholds for hand-picking surviving wild radish plants in-crop to further reduce weed burdens.

For herbicide control of wild radish, pre-emergent options registered for use in WA lupin crops are:

- Simazine (Group C)
- Atrazine (Group C)
- Diuron (Group C).

Wild radish is not highly damaging to yield potential early in the season.

Simazine followed by a top-up application two to five weeks after planting usually provides good control.

Post-emergent herbicides registered to control wild radish in WA lupin crops are:

- Metosulam (Group B)
- Simazine (Group C)
- Metribuzin (Group C)
- Diflufenican (Group F)
- Picolinafen (Group F).

Tips for post-emergent herbicide use for wild radish in WA lupin crops include:

- Use full label rates
- Diflufenican can be used for early control – it is unlikely to kill large weeds
- Metribuzin can cause crop damage to some varieties, exacerbated in colder climates
- Varieties Gunyidi, PBA Leeman and PBA Barlock are more tolerant of metribuzin
- Mixing broadleaf and grass herbicides will damage lupin and should be avoided.[43]

39 Newman, P (2013) We can kill wild radish in lupins if we have enough spray capacity, GRDC DAFWA 2013 Agribusiness Crop Updates paper, www.giwa.org.au/past-crop-updates

40 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

41 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

42 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

43 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

5.7.2 Wild mustard/Indian hedge mustard (*Sisymbrium orientale*)

Figure 9: *Wild mustard is a prolific seed producer but is not a big problem for WA lupin crops*

- Produces vast numbers of seeds (up to 30,000/m^2)
- Causes problems at harvest
- Small seeds can cause grain contamination.
- Not a major weed of WA lupin crops.[44]

Management and control

Table 10: Tactics that should be considered when developing an integrated plan to manage Indian hedge mustard[45]

Indian hedge mustard (*Sisymbrium orientale*)		Most likely % control (range)	Comments on use
Agronomy	Crop choice and sequence	85 (0-99)	Avoid crops with no post-emergent herbicide options.
Agronomy	Herbicide tolerant crops	80 (0-95)	Very useful for non-cereal portions of the rotation.
Tactic	Autumn tickle	25 (10–50)	Use with early breaks to the season and combine with delayed sowing.
Tactic	Delayed sowing	95 (90–99)	Follow by knockdown with non-selective herbicides targeting small weeds.
Tactic	Knockdown (non-selective) herbicides for fallow and pre-sowing control	75 (50–80)	Use high rates to control biennial plants. Tank-mixing with phenoxy herbicides improves control in absence of Group I resistance. Late germinations are not controlled.
Tactic	Pre-emergent herbicides	75 (50–80)	Dry conditions post-sowing reduces herbicide efficacy.
Tactic	Selective post-emergent herbicides	80 (60–90)	Spray young actively growing plants and repeat if necessary. Be aware of resistance status.
Tactic	Spray-topping with selective herbicides	95 (85–99)	Be aware of resistance status. The control range assumes no Group B resistance.
Tactic	Wiper technology	80 (60–95)	Useful tactic in lentils.
Tactic	Grazing – actively managing weeds in pastures	70 (50–80)	Rotationally graze. Use spray-grazing with herbicide suited to pasture species present.
Tactic	Weed seed collection at harvest	50 (10–70)	Useful on early harvested crops.

(SOURCE: GRDC)

44 HerbiGuide, Wild Mustard, http://www.herbiguide.com.au/Descriptions/hg_Indian_Hedge_Mustard.htm

45 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

Wild mustard is found in the WA grainbelt, but is not a major weed of economic importance for growing lupin crops. The pre-emergent herbicide options for control are simazine (Group C) and atrazine (Group C).

Post-emergent herbicide options to control wild mustard in WA lupin crops are simazine and diflufenican (Group F).

5.7.3 Wireweed (*Polygonum aviculare*, *P. arenastrum*)

Figure 10: *Wireweed is a prolific seed producer but is not a big problem for WA lupin crops*

(SOURCE: Agronomo)

- Autumn to early summer germinating, annual or biennial
- Delayed germination makes control difficult
- Competes for moisture and nutrients
- Often causes problems with machinery
- Has phytotoxic properties.[46]

Management and control

Table 11: Tactics to consider when developing an integrated plan to manage wireweed.[47]

Wireweed (*Polygonum* spp.)		Most likely % control (range)	Comments on use
Agronomy	Crop choice and sequence	80 (0–50)	Avoid continuous cereals or broadleaf crops where control is difficult. Avoid growing pulses in heavily infested paddocks. Wireweed increases in triazine tolerant canola.
Agronomy	Herbicide tolerant crops	90 (50–95)	Some imidazoline herbicides provide useful control in legume and imidazoline tolerant crops. Glyphosate will provide good control in glyphosate tolerant crops.
Agronomy	Fallow phase	80 (0–80)	Control early in the fallow to reduce vining (i.e. kill small plants).
Tactic	Inversion ploughing	90 (80–95)	Use once to bury resistant seed deeply then avoid bringing that seed back to the surface for at least 10 years.
Tactic	Knockdown (non-selective) herbicides for fallow and pre-sowing control	90 (75–90)	Glyphosate, dicamba and some sulfonylurea herbicides are the most effective.
Tactic	Pre-emergent herbicides	90 (50–80)	Trifluralin, pendimethalin, chlorsulfuron and triasulfuron provide good control, but are dependent on rain after application.
Tactic	Selective post-emergent herbicides	90 (75–90)	Metsulfuron and dicamba provide good control. Target small weeds for better control. Few options exist in broadleaf crops.
Tactic	Manuring, mulching and hay freezing	90 (50–80)	Good for controlling late germinations and reducing problems in summer fallow.

(SOURCE: GRDC)

46 HerbiGuide, Wireweed, http://www.herbiguide.com.au/Descriptions/hg_Wireweed.htm

47 GRDC (2014) Integrated Weed Management Manual, GRDC Integrated Weed Management Manual: www.grdc.com.au/IWMM

Wireweed tends to germinate during or after crop emergence and competes for soil moisture and nutrients.

Typically, it does not affect lupin yields significantly, but it can cause problems in blocking sowing equipment and/or interfere with harvesting due to its lengthy branching.

It can affect rhizobia bacteria required for lupin nodulation due to its phytotoxic properties and it is tolerant of atrazine.[48]

Pre-emergent herbicide options for control of wireweed in WA lupin crops include:

- Trifluralin (Group D)
- Pendimethalin (Group D)
- Atrazine (Group C).

5.8 Crop-topping for weed control

- Apply a non-selective herbicide (paraquat, Group L) prior to harvest
- Always check label for registration, rate and timing details
- Time application to target weeds at flowering and early grain fill
- This will minimise production of viable weed seed and crop yield loss
- Success requires sufficient gap in physiological maturity between crop and weed
- Ideal time is when 80 percent of lupin leaves have turned brown or fallen off
- Works best with early maturing lupin varieties.[49]

Management when crop-topping

Paraquat is registered for crop-topping in WA lupin crops and can be applied at the 80 percent leaf drop point. Crop-topping at this time has been shown to minimise lupin yield losses in WA.[50]

Short season varieties, such as PBA Gunyidi□, Belara and Mandelup□, typically reach 80 percent leaf drop stage seven to 10 days earlier than longer season varieties, such as Tanjil□, and are well suited to crop-topping.

For annual ryegrass, crop-topping is most effective when the weed is at flowering to soft dough stage. If dough cannot be squeezed from the ryegrass seed, it will be viable even if crop-topping is used. In wet spring conditions, the duration of flowering and podding of the lupin crop can be extended due to the indeterminate growth habit of the crop. This prolongs the time until 80 percent leaf-drop and annual ryegrass can develop past the dough stage before the crop is ready. This highlights that crop-topping is a highly seasonally dependent tool that cannot be used each year unless lupin yield impact is accepted to ensure annual ryegrass is controlled. [51]

(For more information, see Chapter 10).

48 HerbiGuide, Wireweed, http://www.herbiguide.com.au/Descriptions/hg_Wireweed.htm

49 GRDC Fact Sheet (2015) Pre-harvest Herbicide Use, www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

50 GRDC Fact Sheet (2015) Pre-harvest Herbicide Use, www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

51 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

FEEDBACK

MORE INFORMATION

GRDC 'Know More' Video – Chaff carts for HWSC': https://grdc.com.au/Video-KnowMore-West

GRDC RCSN booklet 'The effectiveness of on-farm methods of weed seed collection at harvest time': www.grdc.com.au/CaseStudy-WeedSeedHarvest-Albany

WeedSmart 'HWSC guide and case studies': www.weedsmart.org.au/wp-content/uploads/2013/12/AHRI-Harvest-Weed-Seed-Control-Booklet_2013-version.pdf

WeedSmart webinar 'iHSD': at: https://australianherbicideresistanceinitiative.leadpages.co/ws-webinar-recordings/

5.9 Harvest weed seed control (HWSC) tactics

Figure 11: *The new integrated Harrington Seed Destructor (iHSD) system is one HWSC method that destroys weed seeds by pulverising the chaff fraction as it leaves the harvester.*

(SOURCE: McIntosh & Son)

A major biological weakness of most WA cropping weeds is their seed does not shatter before harvest, providing a good opportunity for removal at this time.

Capturing the weed seed and destroying it substantially reduces carry-over from the lupin crop into the next crop phase.

Common HWSC tactics used in WA include:

- Collecting chaff in chaff carts
- Burning or grazing chaff residue
- Depositing chaff on narrow windrows for burning the next autumn
- Using a seed destruction system to pulverise and destroy chaff and weed seed fraction as it leaves the harvester
- Diverting weed seeds onto permanent tramlines
- Towing a baler behind the header to remove all harvest residue.

These systems remove both resistant and susceptible weed seeds that have survived earlier herbicide applications. This reduces the risk of herbicide resistance evolution and the selection pressure on herbicides.

AHRI research at 25 sites across southern Australia during the 2010 and 2011 harvests found windrow burning, chaff cart and seed destruction systems were equally effective at removing annual ryegrass seed from cropping paddocks.

Each of these HWSC methods led to a 55 percent reduction in annual ryegrass germination the following year.

AHRI research has also shown that seed destruction at harvest consistently destroys 95 percent of annual ryegrass, wild radish, wild oats and brome grass seed present in the chaff fraction. Its trials in WA have also found chaff carts offer a reliable method of catching seed and are very effective at rapidly decreasing large banks of weed seed.[52]

Typically, 45 to 75 percent of annual ryegrass seed and 70 to 80 percent of wild radish seed is collected in a chaff cart.

52 Walsh, M, Aves, C, Powles, S (2014) Evaluation of harvest weed seed control systems, AHRI, Nineteenth Australasian Weeds Conference paper, 4 GRDC Fact Sheet (2015) Pre-harvest Herbicide Use, http://caws.org.au/awc/2014/awc201412881.pdf

Baling behind the header can be a successful method to reduce weed seed banks. Trials have shown this can remove up to 98 percent of the weed seed that enters the header.

But increased mineral nutrient input is required to budget for exported nutrients in the straw and a powerful header is required to tow the baler.

To be viable, a market for the hay is needed – such as an export hay market or feed processing plant.

Burning entire paddocks on WA's sandplain soils needs to be carried out with extreme caution. This is generally undertaken very close to seeding, if at all, and is not recommended for lupin paddocks.

Burning lupin chaff that has been placed in a narrow windrow can be a more effective method than paddock burning to destroy annual ryegrass and radish seed.

The burn kills almost all the seed in the windrow. But seed that has dropped to the ground before going through the header is not controlled and it is best to harvest weedy paddocks first to minimise shedding of weed seed.[53]

5.10 Weed detection technology

Figure 12: *Yuna grower Craig Thompson bought a WEEDit precision sprayer seven years ago and says it has become a crucial tool for summer weeds control.*

(SOURCE: GRDC)

Weed-detecting technology is being used in parts of WA, typically to target and spray individual weeds that survive a summer/autumn glyphosate application and an alternative knockdown herbicide.

This technology is well suited to detecting and killing patches of weeds across large-scale properties, using optical sensors to turn on spray nozzles only when green weeds are detected. This can reduce total herbicide use and cost per hectare (after accounting for the initial outlay cost for machinery).

This new technology also has potential to map troublesome weed patches so these areas can be targeted with a pre-emergent herbicide before sowing.

The two weed detecting systems available in Australia are WeedSeeker® and WEEDit®.

A minor use permit was issued for all Australian states for herbicide use with these systems and is valid until February 28, 2019 (to be reviewed annually).

The permit (PER11163) allows growers to use about 30 different selective grass herbicides from seven MOA groups and higher rates of paraquat and diquat.

53 White, P, French, B, McLarty, A (2008) Producing Lupins, Department of Agriculture and Food WA, Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

5.11 Decision support tools

Adoption of successful IWM involves complex interactions, multiple-year timeframes, many possible interventions, major environmental influences and high levels of uncertainty.

The use of computer-based models can be a valuable tool to aid decision making.

Developed by AHRI, with GRDC funding, the Ryegrass Integrated Management (RIM) model evaluates the long term profitability of annual ryegrass control methods and reducing the weed seedbank.

Weed Seed Wizard is a simulation tool, developed in a national collaboration, that uses paddock management information to predict weed emergence and crop losses now and in the future to help growers devise effective IWM plans.

5.11.1 Ryegrass Integrated Management (RIM)

RIM enables users to assess the effectiveness and budget implications of 10-year cropping and weed management scenarios using up-to-date economic parameters.

It has options for four crops, including lupin, three pastures and 43 practices that include herbicide use and rates, timing of application, soil preparation, crop type, grazing and HWSC options.

Graphs can be produced and exported to other software programs for analysing annual ryegrass survivors, gross margins across 10 years, yield loss from competition and ryegrass seedbank levels. See the link to this resource in the 'More information' box.

5.11.2 Weed Seed Wizard

This model can investigate the impact of a wide range of IWM strategies (such as HWSC, increased crop competition, rotation change and various seed set controls such as crop-topping and hay making) on weed and weed seed numbers.

It was developed by DPIRD in partnership with The University of Western Australia, University of Adelaide, the New South Wales Department of Primary Industries and the Department of Agriculture Fisheries and Forestry in Queensland, and supported by GRDC.

The user enters site-specific weather data and soil type, the weed species to be investigated and information about past and future weed management.

The model uses real weather data and gives an estimate of crop yield loss as a result of weed pressure from a range of species. See the link to this resource in the 'More information' box.

MORE INFORMATION

RIM: www.ahri.uwa.edu.au/rim

RIM user guide: http://ahri.uwa.edu.au/~ahriuwae/wp-content/uploads/2014/09/611-RIM-2013-User-guide.pdf

DPIRD Weed Seed Wizard: https://www.agric.wa.gov.au/weed-seed-wizard/weed-seed-wizard-download-and-help